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Nutritional Evaluation and Cost Analysis of Water Hyacinth (*Eichhornia crassipes*) as a Replacement of Fish Meal in the Diets of GIF Tilapia

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ABSTRACT

Background: Aquaculture's explosive growth has made it more and more dependent on outside feed sources. Fish meal serves as the primary source of protein for external feed inputs. These days, it's difficult to provide a high-protein diet at a reasonable price. Numerous investigations have been carried out to assess the viability of using plant-based protein sources in place of fish meal in a tilapia's diet.

Methods: The current study was planned to study the performance of Genetically Improved Farmed Tilapia (GIFT) when fed with Water Hyacinth *(Eichhornia crassipes)*. In the present trial, major feed ingredients were mixed in the feed at different concentration *viz*., 20%, 40%, 60%, 80% and 100%. Every day the fishes were fed at the rate of 5% of their body weight. The experiment was conducted for a period of 90 days and the sampling was carried out once in a fortnight.

Result: This study suggests replacing fish meal at low concentrations or no replacement tends to increase the growth of the fish without compromising the cost of the feed. The water hyacinth diet helps to cut down the price to a greater extent as the inclusion levels are less and helps to find a new alternative in the feed industry.

Key words: Alternative, Fish meal, GIF tilapia, Performance, Water hyacinth.

INTRODUCTION

Aquaculture has increased because of stagnating marine capture output, which aids in closing the gap between supply and demand. Aquaculture is a significant source of protein for humans and has the potential to provide jobs as well as improve commercial and recreational fishing. With rapid production growth and significant changes to feed components and production technology, aquaculture has consequently become more integrated into the global food chain (Rosamond *et al*., 2021). In 2020, production from aquaculture reached 87.5 million tonnes and in that 66% of world fishproduction was consumed as food (FAO, 2022). Global fish production is estimated to have reached about 185.4 million tonnes in 2022 (FAO, 2024). Many people have ingested fish as part of their cultural traditions and for certain communities, fish and fisheries products represent a substantial source of food and critical nutrients (Priyatharshini *et al*., 2024). Fish meal is a primary source of protein for cattle, poultry, pigs and the aquaculture business is in rivalry with it due to its high prices. Fishmeal is frequently recognised as the best dietary protein source for many fish species (Hertrampf *et al*., 2012; Ruby *et al*., 2022). Fish meal has historically been the favoured dietary protein source for many farmed fish species in various regions of the world due to its amino acid composition, vitamin and mineral content, high digestibility, palatability and unidentified growth factors (Miles and Chapman, 2006). Fish meal is also utilized for animal production (FAO, 2007). The supplied diet must contain the necessary nutritional requirements for the fish to ensure the best growth (Ghomi *et al*., 2012). Due to the greater costs and scarcity, fish meal and fish oil are rarely used in fish feed, which is one of aquaculture's main objectives. Research in fish nutrition that will use non-traditional, locally accessible (alternative, low cost) feed ingredients of plant protein sources and without reducing the quality of the feed is urgently needed in order to realise aquaculture development sustainably. This is also essential to the overall success of aquaculture development, growth and expansion (Suleiman and Lado, 2011; Zenebe Tadesse *et al*., 2012). To accelerate the growth of channel catfish fingerlings, dehydrated water hyacinth has been added to

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their diet. Additionally, it has been observed that after chemical treatment, water hyacinth degradation releases nutrients that support phytoplankton growth and hence boost fish output. Because the water hyacinth leaf can absorb nutrients that the petioles cannot, the leaves are always extremely opulent in a rich water body (Asmath *et al*., 2024). Since the water hyacinth leaf has a dry matter protein content of 55.4% and is particularly high in leucine (5.1%) and phenylalanine (3.1%), it can be used as an alternate protein source for tilapia (Rajan Pandiya Gowtha *et al*., 2023). Highest crude protein level is found in the leaves and lowest level in the petioles. According to World Fish, India will be able to produce 1 million metric tonnes of tilapia by 2024-2025 (Gaikwad *et al*., 2021; Yuvarajan *et al*., 2023). Fishery professionals refer to tilapia as "aquatic chicken" due to its quick evolution and simplicity of cultivation, which have led to its widespread cultivation in the modern world (Maclean, 1984). MoreMonosex GIFT tilapia are being raised by fish farmers in our country (Bhendarkar *et al*., 2017; Bhendarkar and Brahmane, 2021a). Therefore, attempts are made to substitute the protein in fish meal with that from other sources of plant and animal protein in the diets of GIF Tilapia. The main aim of the study is to investigate the incorporation of plant protein source in the diet in order to reduce the cost of the feed.

MATERIALS AND METHODS

Experimental fish and feeding trial

The experiment was carried out at Davis Farm, Keeranoor village, Thoothukudi district during the year 2022. The experimental fish, which are GIF tilapia, were obtained from a Madurai, Tamil Nadu, private fish farm. The fish were graded before the experiment to get an individual average weight that varied from 6.0 to 6.5 g. The fish were then allowed to acclimate in the cement aquariums for ten days. Commercial feed was given to the fish during the acclimation period. Each tank holds 30 fish, each weighing between 6.0 and 6.5 g. Each tank is One ton capacity for holidng the fishes. Fish were fed at a rate of 5% of their body weight three times a day. Two equal portions of the feeding regimen were given twice a day, at 10:00 am and 4:00 pm. Every day, 40% of the water in each tank was exchanged. The water quality metrics were tracked throughout the trial and the mean values were as follows: Temperature 28.17±012°C, pH 7.45±0.13, dissolved oxygen 5.47±0.07 mg/l, alkalinity 124.05±0.4 mg/l, hardness 59.25±0.0.01 mg/l and ammonia nil.

Experimental diets

Six experimental isoprotein diets containing 32% levels of crude protein were formulated. Feed ingredients such as Water Hyacinth (WH) and Fish Meal (FM) were selected for this study. One month old water hyacinth leaves was collected from keeranoor canal (Tuticorin district). Fish meal was collected from the fish meal production plant located in Tuticorin district, Tamil Nadu. Proximate composition analysis was performed on the chosen feed items. The ingredients were dried well by spreading in trays and powdered. The major ingredients used for the preparation of feed are Water Hyacinth and Fish meal. The other feed additives were added to the experimental feed at varying concentrations after being purchased from the nearby market. With the exception of the vitamin and mineral mixture, all the components and major ingredients (Water Hyacinth and Fish Meal) were thoroughly combined according to the ratio, formed into a ball and cooked in a pressure cooker (121°C) for ten to fifteen minutes. Thorough kneading ensured that the ingredients were distributed evenly. After the prepared paste had cooled, a blend of vitamins and minerals was added. After that, a hand pelletizer with a die size of 2 mm was used to extrude the pellets from each dough separately. For the experiment, the pelletized meals were dried individually and kept in various airtight containers. The ingredients composition of feeds used for different experiments including control feed is presented in Table 1. These major ingredients are mixed in the feed at different concentration *viz*., WH *viz* 20%, 40%, 60%, 80% and 100%. The control feed was prepared without adding WH.

Growth performance

For growth analysis, the fishes were collected from all tanks using hand net and the weight (g) were measured once in fifteen days interval using a digital balance. At the end of the experimental trail, growth performances were calculated and assessed by means of weight gain (WG), specific growth rate (SGR), protein efficiency ratio (PER), thermal growth coeffecient and survival rate (SR) using following fish growth parameters calculations/formulae.

$$\text{Weight gain} = \text{Final weight (g)} - \text{Initial weight (g)}$$

Specific growth rate (SGR) =

$$\frac{\text{ln final weight} - \text{ln initial weight}}{\text{Number of days}} \times 100$$

Protein efficiency ratio (PER) =

$$\frac{\text{Body weight gain (wet weight)}}{\text{Crude protein fed}}$$

Survival rate (SR) =

$$\frac{\text{Total number of animal harvested}}{\text{Total number stocked}} \times 100$$

Thermal growth coeffecient (TGC)= [Final weight^1/3-Initial weight^1/3] [Mean water temperature (°C)*duration of days)]*100

Digestibility analysis of experimental feeds

The indirect method was used to measure the apparent protein digestibility coefficients of the diets and each experimental feed contained 0.5% of an inert marker, chromic oxide (Cr_2O_3) (Gomes *et al*., 1995). Faeces was collected daily from each tank fed with experimental feed to evaluate the digestibility of the different feeds.Faeces were collected by siphoning them out 1-2 hours after feeding. The faeces were gathered and stored in a refrigerator in an airtight plastic bag for further analysis. The apparent digestibility of experimental feeds is given in Table 2. According to Takeuchi (1988), chromium analysis for digestibility assessment was carried out by determining the amount of Cr_2O_3 present in experimental meals and faeces. According to Glencross *et al*. (2012), the diets' apparent digestibility coefficients (ADC) for dry matter, nutrients (such as protein, lipids and carbohydrates and energy) were calculated using the following formulae;

$$\text{Apparent digestibility coefficients (ADC) of dry matter (\%)} = [1-(a/a')] \times 100$$

$$\text{Apparent digestibility coefficients (ADC) of nutrients or energy (\%)} = [1-(a/a' \times b/b')] \times 100$$

Where:

a= Cr_2O_3 concentration in feed.
a' = Cr_2O_3 concentration in faeces.
b= Nutrients or energy content in feed.
b'= Nutrients or energy content in faeces.

Economic analysis

Economic analysis for different test diets (Table 3) were performed for 1000 grams of feed. Comparison of weight gain and cost was studied to estimate the feasibility for aquaculture enterprises.

Statistical analysis

Statistical analysis was made by means of SPSS VERSION 16.0 through analysis of variance (ANOVA). Students 't' test was also performed at 95% confidence level. For post hoc comparison of mean (P<0.05) between different groups, Duncan's multiple range test was performed.

RESULTS AND DISCUSSION

Growth performance and digestibility

The water hyacinth is incorporated in the feed at different concentrations *viz*., 20, 40, 60, 80 and 100%. The mean weight gain of the fishes fed with control was 138.73±0.06 g which is higher than that of the fishes fed with Control (131.78±0.11 g). The mean weight gain of fishes fed with other concentrations like 60, 80 and 100% showed decreasing trend.

Table 1: Formulation and chemical composition of the experimental diets.

Ingredients	Control	Fish meal replacement with water hyacinth				
		20%	40%	60%	80%	100%
Fish meal	30	24	18	12	6	0
Water hyacinth	0	6	12	18	24	30
Ground nut oil cake	12	23	33	44	58	67.8
Rice bran	20	20	18	15	7	0.1
Wheat flour	25	10	10	7	2	1
Corn flour	12	16	8	3	2	0.1
Vitamin + mineral mix	1	1	1	1	1	1
Proximate composition						
Moisture (%)	9.79	9.30	9.66	10.04	9.66	10.20
Crude protein (%)	32.16	32.06	32.14	31.85	32.06	32.03
Crude fat (%)	12.74	11.72	10.63	11.5	12.57	11.65
Crude fiber (%)	12.56	12.11	11.63	12.67	11.84	12.21
Ash (%)	11.83	12.15	12.80	12	11.19	10.73
CHO (%)	20.6	22.7	23.1	22.55	23.45	23.75
Gross energy (kcal/100 g)	376	355.15	361.1	355.8	363.25	373.8

Table 2: Apparent digestibility coefficient (ADC) for different experimental diets.

Experimental groups	ADC (%) of dry matter	ADC (%) of protein	ADC (%) of lipid	ADC (%) of carbohydrate	ADC (%) of energy
T1 (20%)	72.52 ± 0.40^{a}	79.78 ± 0.5^{a}	89.70 ± 0.29^{b}	77.83 ± 0.44^{c}	81.15 ± 0.07^{d}
T2 (40%)	69.52 ± 0.15^{a}	78.36 ± 2.19^{b}	85.46 ± 0.07^{ab}	74.76 ± 0.20^{b}	79.43 ± 0.63^{c}
T3 (60%)	71.83 ± 0.09^{a}	78.40 ± 2.14^{c}	88.32 ± 0.43^{ab}	75.10 ± 0.18^{b}	79.76 ± 0.70^{c}
T4 (80%)	65.78 ± 1.01^{a}	76.96 ± 0.02^{a}	79.23 ± 1.91^{a}	72.15 ± 0.71^{a}	73.30 ± 0.09^{a}
T5 (100%)	66.51 ± 0.71^{a}	77.06 ± 3.82^{c}	82.94 ± 0.63^{ab}	72.60 ± 1.49^{a}	76.14 ± 0.68^{b}
C1	67.36 ± 0.18^{a}	77.47 ± 1.49^{a}	84.52 ± 0.59^{ab}	72.71 ± 0.55^{a}	76.78 ± 0.06^{b}

Note: Values (mean±SD, n=2) in the same column with different superscript differ significantly (p<0.05).

With regard to the average daily growth the fishes fed with 20% showed 1.54 g which is not similar to 60% and 100% when compared to other treatments. High Survival is seen in 20% and lower in 80%. Bio growth performances of GIFT Tilapia fed under different inclusion level of water hyacinth feed is given in Table 4. Mean body weight of GIF Tilapia fed with different inclusion levels of water hyacinth is shown in Fig 1.

Selvaraj *et al*. (2021) discovered that water hyacinth could replace up to 20% of fish meal in tilapia diets without compromising growth or feed utilisation. Azubuike *et al*. (2016) discovered that water hyacinth may replace up to 30% of the fish meal in tilapia diets, however higher levels of water hyacinth resulted in slower growth. Nartey *et al*. (2000) discovered that water hyacinth may substitute up to 40% of the fish meal in tilapia diets, but that higher levels

Table 3: Economic analysis of feed ingredients used in test diets.

Variables	C1 (Control)	T1 (20%)	T2 (40%)	T3 (60%)	T4 (80%)	T5 (100%)
Seed cost (Rs)	180	180	180	180	180	180
Feed cost (Rs)	992.38	964.35	868.27	811.39	757.50	720.82
Total cost (Rs)	1172.38	1144.35	1048.27	991.39	937.50	900.82
Total feed consumed (kg)	12.30	12.78	12.37	12.41	12.11	12.20
Total production (kg)	8.29	8.74	8.37	8.42	8.14	8.22
Selling price (Rs/kg)	150	150	150	150	150	150
Total amount realized (Rs)	1243.35	1310.36	1255.46	1263.02	1220.54	1232.55
Net income (Rs)	70.97	166	207.18	271.63	283.03	331.73
Cost of production/kg (Rs)	141.44	131	136.73	117.74	115.22	109.63

Table 4: Bio-growth performance of GIFT Tilapia fed with water hyacinth incorporated diets.

Parameters	C1 (0%)	T1 (20%)	T2 (40%)	T3 (60%)	T4 (80%)	T5 (100%)
Survival (%)	95.33^{a}	96.66^{c}	88.33±1.66^{a}	95±1.66^{a}	90±3.33^{a}	93.3±3.3^{a}
Initial body weight (g)	6.37±0.15^{a}	6.86±0.01^{b}	6.42^{a}	6.43±0.007^{a}	6.25±0.33^{a}	6.37±0.15^{a}
Final body weight (g)	138.15±0.26^{c}	145.59±0.04^{f}	139.49±0.6^{d}	140.33±0.13^{d}	135.61±0.75^{a}	136.95±0.14^{b}
Weight gain (WG) (g)	131.78±0.11^{c}	138.73±0.06^{g}	133.07±0.65^{d}	133.9±0.12 ^{e}	129.36±0.41^{a}	117.98±1.03^{b}
Weight gain (WG) (%)	38.15±0.26^{c}	45.59±0.04^{f}	36.49±0.65^{d}	40.33±0.13^{d}	35.61±0.75^{a}	36.95±0.14^{b}
ADG (%)	1.46±0.001^{c}	1.54±0.0007^{g}	1.47±0.007^{d}	1.48±0.001^{e}	1.43±0.004^{a}	1.45±0.001^{b}
SGR (%)	3.43±0.003^{a}	3.588±0.001^{a}	3.50±0.019^{a}	3.45±0.05^{a}	3.34±0.005^{a}	3.32±0.002^{a}
FCR	1.552±0.04^{ab}	1.535±0.003^{a}	1.549±0.01^{ab}	1.54±0.002^{ab}	1.56±0.008^{b}	1.558±0.01^{b}
FER	0.642±0.01^{de}	0.651±0.01^{cd}	0.645±0.05^{e}	0.647±0.1^{de}	0.640±0.03^{ab}	0.641±0.004^{a}
PER	4.11±0.003^{c}	4.33±0.001^{g}	4.15±0.02^{d}	4.18±0.003^{e}	4.04±0.01^{a}	4.07±0.005^{b}
TGC	1.75±0.001^{b}	1.68±0.01^{a}	1.85±0.01^{d}	1.80±0.0003^{c}	1.76±0.01^{bc}	1.77±0.02^{bc}

Note: Values (mean±SD, n=2) in the same rows with different superscripts differ significantly (p<0.05).

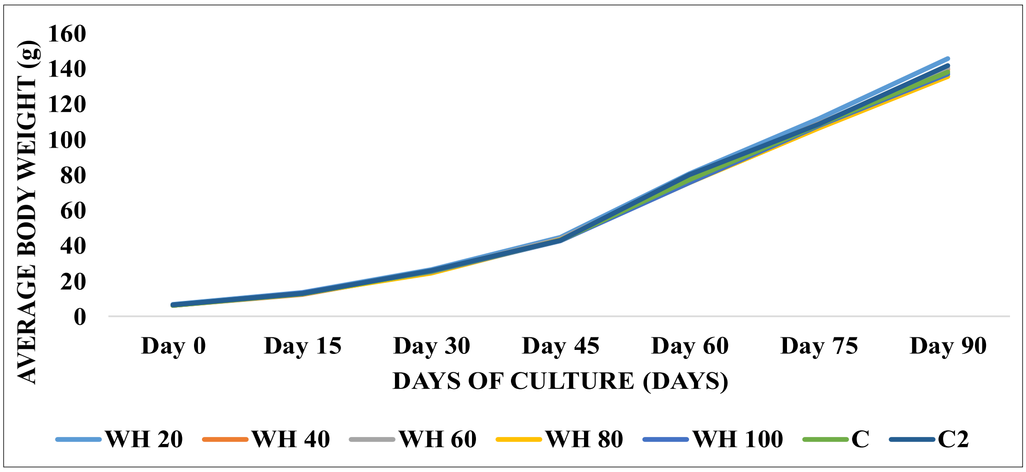

Fig 1: Mean body weight of GIFT Tilapia fingerlings fed with different water hyacinth incorporated experimental diet.

of water hyacinth resulted in higher levels of oxalates in the fish.

In the present study the fishes in the treatment T1 (20% WH) showed higher mean body weightfollowed by T3 (60% WH), T2 (40% WH) and C1 (0% WH). The lowest mean final body weight was seen in T5 (100% WH). T4 (80% WH) showed lower performance than T1, T2 and C1.

El-Sayed (2003) discovered that water hyacinth meal, at levels up to 20%, has a favourable influence on fish growth. However, higher levels of inclusion (30% or above) might be detrimental to growth. Emshaw *et al*. (2023) discovered that fermented water hyacinth can boost fish development performance. This is most likely due to the fact that fermentation reduces the fibre level of water hyacinth, making it more digestible for fish. Bake *et al*. (2015) discovered that the type of fish used can influence the responsiveness to water hyacinth diets. Omnivorous fish, such as Nile tilapia, appear to outperform herbivorous fish, such as common carp, on water hyacinth diets.

Riechert and Trede (1977) published the results of a preliminary indoor laboratory study on the feeding of water hyacinths to grass carp conducted in Germany. They discovered that feeding the fish water hyacinth leaves resulted in a feed conversion ratio (FCR) of 1.54.

Paiva *et al*. (2009) studied the growth of Nile tilapia (*Oreochromis niloticus*) fingerlings fed diets with varying quantities of water hyacinth leaf meal in Brazil. They discovered that fish grew well on diets containing up to 25% water hyacinth leaf meal but that higher amounts resulted in lower growth and survival.

According to Akter *et al*. (2014), rohu fingerlings fed a 40% water hyacinth diet showed no negative effects on their health or behaviour. Akter *et al*. (2019) discovered that rohu (*Labeo rohita*) fingerlings fed a 40% water hyacinth diet grew faster than rohu fingerlings fed a 20% water hyacinth diet.

Abol-Munafi *et al*. (2012) found that meals containing water hyacinth had a worse apparent digestibility of dry matter, crude protein and gross energy than diets containing fish meal. However, the water hyacinth's digestibility increased after it was fermented. In contrast to 45% in unfermented water hyacinth, crude protein apparent digestibility in fermented water hyacinth was 56%.

According to Abdel-Fattah and Mamdouh (2008), the apparent digestibility coefficient of carbohydrate in water hyacinth and fish diets was 60.56%. This number was much lower than the apparent carbohydrate digestibility coefficient in fish meal, which was 80.44%. According to Wee (1991), the apparent digestibility coefficient of carbohydrate in fermented water hyacinth is 76.8%. This figure was much greater than the apparent carbohydrate digestibility coefficient in unfermented water hyacinth, which was 56.0%. According to A-Rahman Tibin *et al*. (2012), the apparent digestibility coefficient of carbohydrate in water hyacinth-included fish diets dropped as the amount of water hyacinth in the diet rose.

These results were in accordance with the present study which showed that water hyacinth at 20% replacement of fish meal has higher growth performance when compared to control and other treatments. These studies suggest that the apparent digestibility of water hyacinth included fish diets can be improved by processing the water hyacinth. However, even with processing, the digestibility of water hyacinth is still lower than that of fish meal.

The present study showed better growth performance in 20% replacement of fish meal. The proper handling and preparation of feed can also contribute to the positive result. The replacement showed no negative impact on the fish.

Economic analysis

The economic analysis of combination diet of water hyacinth incorporated diets were studied for the following variables like seed cost, feed cost, total cost, cost of production/kg, total amount realized, net income, net income/kg. The values for the calculated variables were shown in Table 4. The cost of production/kg was seen higher inC1 (Rs.141.44) and the lowest cost of production was seen in T5 (Rs. 109.63).

Statistical analysis

The statistical analysis like Student's t test, Duncan multiple range test (Duncan, 1955), One way ANOVA was done with the help of Microsoft excel and SPSS 16.0. Students 't' test affirmed that mean growth value showed significant difference between different inclusion level of water hyacinth.

One way ANOVA of the data collected affirmed that among different inclusion level of water hyacinth diets, mean growth values showed significant different between the test diet. Similarly, time bound variations also showed significant difference.

CONCLUSION

The feed prepared from water hyacinth had showed better than control when compared to other diets. But the digestibility is better in the diets prepared from the combination feed. The growth is more or less similar to the control diet which shows that the water hyacinth feed is also possible in including in the diets of GIFT. The net income/kg showed that the highest value was found in WH 100%.

Thus, there are various advantages to using WH as fish meal alternatives. For starters, it is a sustainable protein source. Water hyacinth is a fast-growing plant that can be collected in wastewater Second, it is reasonably priced. Water hyacinth is a low-cost crop that can be cultivated on a small scale. Third, is high in important amino acids. Water hyacinth is a significant source of lysine.

Fish meal can generally be replaced by using WH. It might be used instead of regular fish meal. High quality, affordable and sustainable tilapia diets can be made using WH. It helps to decrease the impact of aquaculture on the environment. It may help improve the nutritional content of tilapia diets. Thus it help to reduce the price of tilapia farming. Water Hyacinth will probably be used more and more frequently in the aquaculture sector as research on them advances.

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Data availability statement

The data that support the findings of this study are available within the article.

Conflict of interest

The authors declare that they have no conflict of interest.

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